Internship initiating to experimental research

Liquid films subjected to thermal strains

Internship report of Thibaut Dauhut

Final year of physics degree, PhyTEM course

From May 24th to June 27th, 2010

1. Internship description

a. Obtaining the internship

The "statistical physics days" are an annual event organized by the ESPCI (Ecole Supérieure de Physique et Chimie Industrielle de Paris). I attended the series of lectures in the afternoon of January 28th, 2010. Nicolas Adami, PhD student of the University of Liege, was the first to present his work on liquid films subjected to thermal strains. I found his topic of research extremely interesting but I did not have the time to speak directly with him at the end of the lectures. Instead, I looked for him on the internet and found only his facebook page. I sent him a personal message, explaining that I had liked his presentation and asking whether his laboratory would have the possibility to welcome me for an internship in June. A few days later I received a positive answer from him.

b. Foster laboratory

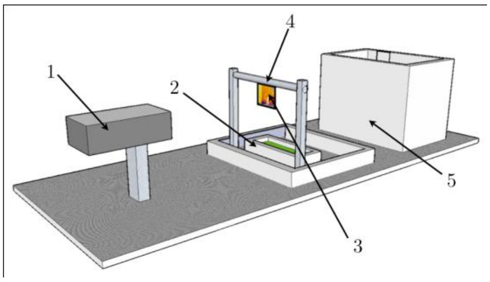
The GRASP (Group for Research and Application in Statistical Physics) is a laboratory of the physics department of the University of Liege. It is located on the Sart-Tilman campus. It is led by the ordinary professor Nicolas Vandewalle and is also formed of a part-time lecturer, two FNRS researchers, two post-doctoral researchers and five PhD students. The GRASP focuses mainly its investigations on more or less complex fluid systems (granular materials, foams, microfluidics…). As current studies we can mention: drops impact on granular surface, behavior of liquid-foam interface of a vibrating system, organization of induced magnetic dipoles, granular system compaction measures and simulations etc. I have been mainly supervised by Nicolas Adami, PhD student at the GRASP and FNRS aspirant. His PhD topic is the study of liquid films under thermal strains. I began by taking one of his experiments up, to manipulate then on a bit different device developed on the occasion of my internship.

c. Experiment

We form a liquid film using a solution of water – glycerol – surfactant that we hold in a vertical rectangular metallic frame. This film is constituted by two interfaces of surfactant between which the solution is confined. Under the influence of gravity, this film flows between the interfaces causing the drainage phenomenon. This is balanced by the solution supply to the film made of a pump system. This is realized by a lengthways split cylinder in which we inject the surfactant solution with a given and constant flow. The bottom bar allows the heating of the film on its full width by hot water circulation at chosen temperature. This is the classic situation of Rayleigh-Bénard cells. Raw experimental data are pictures recorded by an infra-red camera and the iMovie software. Their processing is realized by the imageJ and gnuplot software. The device is completed by an aquarium placed behind the film and filled up with a classic refrigerant liquid (water – ice – salt mixed) in order to get a better contrast in temperature.

Figure 1: Experimental device without heating system

1. Infra-red camera
2. Water-surfactant-glycerol solution tank
3. Studied film
4. Upper bar feeding the film with solution
5. Aquarium containing refrigerant liquid



2. Work done

a. Manipulations

i. First week

In order to accustom myself to the equipment, I began working on Nicolas' initial experiment. Unlike the situation of Rayleigh-Bénard cells, the aim was to realize a local heating rather than a full-width one. Thus, the heating device was different: it was not the bottom bar but a metallic arch in which hot water circulated and which passed right through the film. Not to do again exactly what has already been done, I used Dreft©, a commercial surfactant, instead of the surfactant solution usually prepared in laboratory. Already with that device, I was able to observe the characteristic phenomenon of "plume": it is a convective movement of warm fluid in the film which has a mushroom shape (see by example Figure 3, left, where we can observe two plumes).

ii. Data acquiring

As previously said, phenomena observation in the film and data acquiring is realized by using the infra-red camera and the iMovie software. The videos are recorded as sequences of pictures (called "stacks") which will be analyzed and processed thanks to ImageJ. In order to make easier this processing, it is crucial to get the best possible pictures, thus the camera setting has a pivotal importance. Indeed the camera allows to choose a central temperature and a range of interest. This calibration is not easy, we have to target what we want to observe. For instance, if we want to study plumes growth we prefer a narrow range in order to get a better contrast whereas if it is the general circulation in the film which interests us we choose a wider range. Those choices of camera setting become easier only with the habit and the fact of having already processed the data. I worked four days on stacks acquiring because, in addition to calibration, data uploading by iMovie was often quite long. In order to get correct measurements, different other instruments of the device have been calibrated (for example, the pump, cf. Figure 5 in Appendix).

iii. Observations

With an already significant number of stacks, it became important to know which phenomena were substantial in each of them. The observation in the process of acquiring and a posteriori has confirmed us the existence of different rates of flow for the explored values of the control parameters (temperature, flow, and height). Thus, we have decided not to acquire systematically the data during the manipulations but to bring more importance to the observational work. By building a phase diagram (see Figure 2), we will be able to define more clearly an interest area within the set of the control parameters. Eventually we will be able to plan again manipulations and more accurate acquiring.

b. Data processing

i. Phase diagram

The phase diagram setting up offers us an overall view of the possible rates of flow of our system. I tried to explore the widest area within the set of the control parameters: heating temperature, flow feeding the film, height of the support frame but also solution viscosity. The latter parameter has been lastly used and does not appear on the diagram of Figure 2. I have worked from this perspective for six days. It has not always been easy to distinguish the different rates of flow and to give an account of them with pictograms. I have voluntary tried to convey at maximum the details of my observations even if it means cramming the diagrams with pictograms because I estimate that we will always be able to cut them eventually.

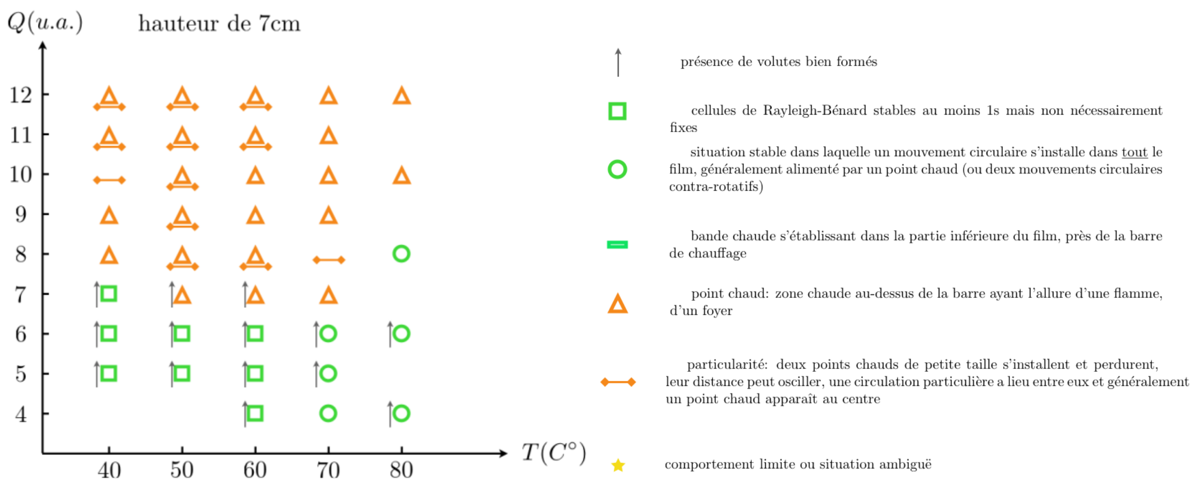


Figure 2: Phase diagram and legend

ii. Computer analysis

Stacks processing is realized thanks to pre-existent software like ImageJ which we implement with one's own plug-in. This is why programming has a special importance in researcher job. That internship has been for me the opportunity to initiate me to Java language. I have also put in practice my knowledge about the gnuplut softaware, with which I learnt too to fit curves (see Figure 5). Figure 3 shows a typical picture taken by the camera and a spatio-temporal diagram corresponding to one series of pictures acquired during experiments.

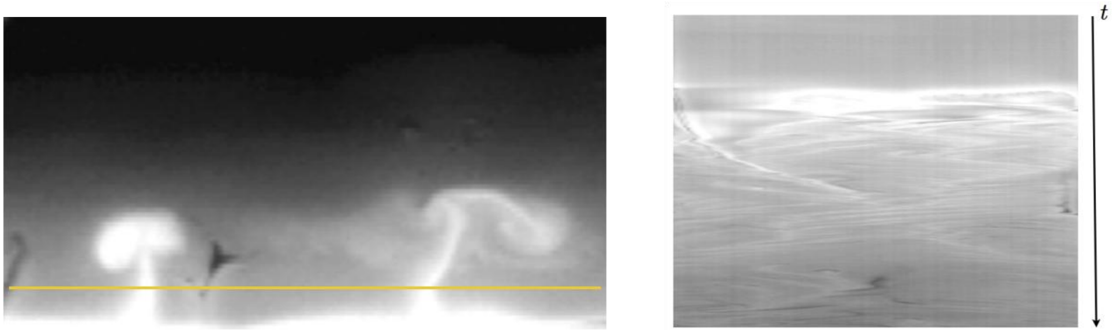


Figure 3: Left: a typical picture taken by the camera. The yellow line represents the interest area for analysis. Right: the matching spatio-temporal diagram.

iii. "Tracking" problem

In order to explain the "tracking problem" in computer analysis I will take the example of plumes' number and position detection in a video. Using a spatio-temporal diagram like on Figure 3, we can see the intensity varies according to the time on the yellow line drawn on the video via ImageJ. If we effectively observe plumes on the non-processed video, we can associate intensity peaks to plumes presence. The aim of the tracking is to detect plumes presence on an intensity curve. We have also to program so that the computer, which has absolutely no idea of what a plume is, would be able to detect them. Of course, it can detect maxima of a curve, but the data are "noised" and the numerous local maxima disturb the plums detection.

During my internship, I had the occasion to develop several methods of detection. The first one consists to take all the maxima of the intensity curve to draw a smoother curve and then to repeat the process in order to get a list of the main maxima which could correspond to plumes. Curves analysis revealed flaws in this method. Some maxima needed only two iterations to be detected and were deleted at the third whereas other points were mistaken for plumes position and needed a third iteration to be deleted. This method depended too much on the pattern of the analyzed intensity curve.

After discussion, I tried the convolution method on intensity curves with the typical pattern of a plume. I got then more or less accurate peaks in the plumes region. To detect them we just needed to make a judicious choice of threshold values which allowed us to pin point the maxima. Figure 4 illustrate those two methods used for plumes detection.

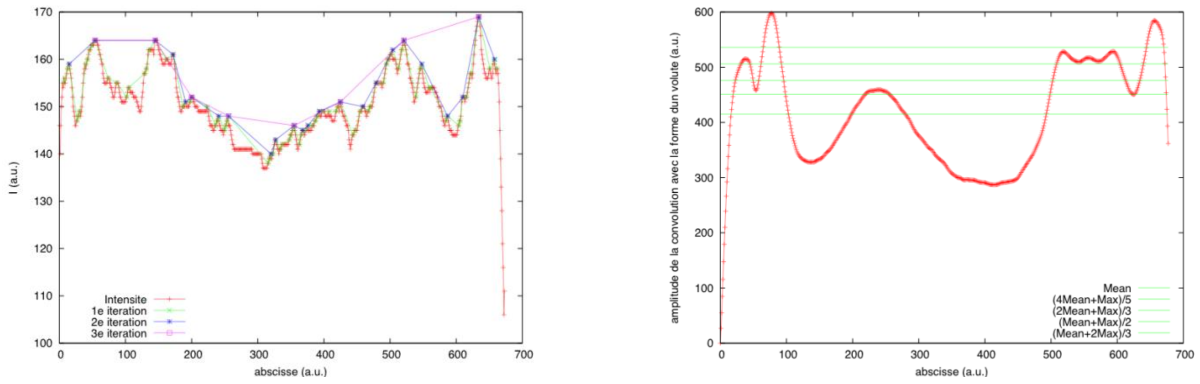


Figure 4: Left: maxima method. Right: convolution method.

After checking, we get a quite correct number of plumes per picture, close to the number we find by counting with naked eye. Nevertheless the upper-described methods do not allow us to get enough satisfying results and need to be more developed. An example of the number of plumes according to the time is given in Appendix (Figure6).

iv. Further investigations

My internship ended while I was having the possibility to study a lot of phenomena inherent to the system. For instance, we realized that the influence height of the Rayleigh-Bénard cells fluctuates according the time when the rate flow allows them to appear. I also acquired stacks which allow to study heat transfer from the bottom bar to the film.

3. Initiation to research

a. Experimental research

During my internship I realized that observational work is primordial to the idea progression. To detect phenomena in each manipulation conditions, we must determine relevant criteria allowing us to pin point them and also develop later manipulations in order to observe them better. Here are the determining choices of the researcher: what to search? How? We should have the experienced eye to detect the relevant phenomena within the manipulation artefacts but keep also curiosity to ask at best the data, not to let new phenomena.

b. Scientific publication

This internship has also been for me the occasion to initiate myself to a scientific publications edition format which has become almost conventional: LateX language. I used it to write the French version of this report and I received advice from my internship master for that.

c. Team work in laboratory

I had the opportunity to attend to a laboratory meeting where two PhD students, their master and a researcher participated. Each has presented the advance of one's results and everyone was able to give their opinion, advice, questions or propose a new reasoning. I quickly understood that those exchange moments in the research team have a primordial importance. They allow taking distance with one's results, benefiting from the external regard and the experience of one's colleagues. It gives without doubt a new impulsion to anyone's work and everyone enjoys it.

d. Personal evaluation

I am extremely satisfied of my internship for several reasons. Overall I enjoyed a lot the availability and the benevolence of my internship master and the friendliness of the whole laboratory team. Indeed, the GRASP team has been particularly welcoming to me and I felt working as a full-fledged researcher. Nicolas, my internship master, let me manipulating with confidence and has taken the time to initiate me to useful software for, among others, data processing, programming and results presentation. By discussing with him and the rest of the team I have been able to confront my experimental reasoning to theirs and it has been very fulfilling for me.

Appendix

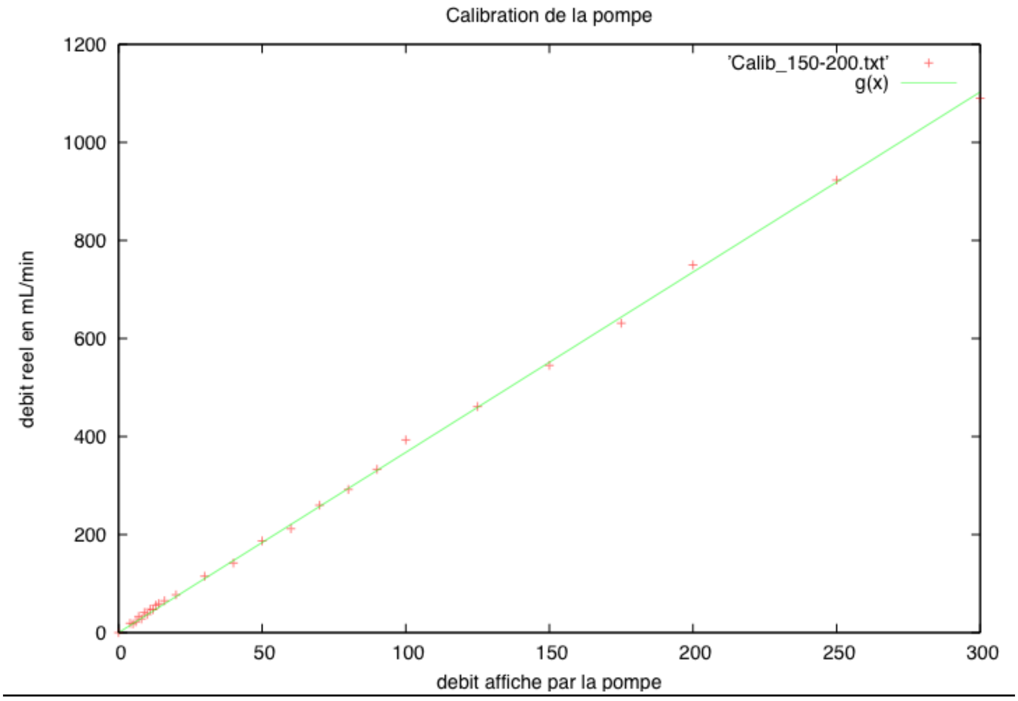


Figure 5: Pump calibration.

Linear curve fitting by gnuplot gives as multiplicative factor a=3.67 ± 0.02 mL/min. This result is viable only for the considered solution, here water-surfactant solution with 10% of glycerol.

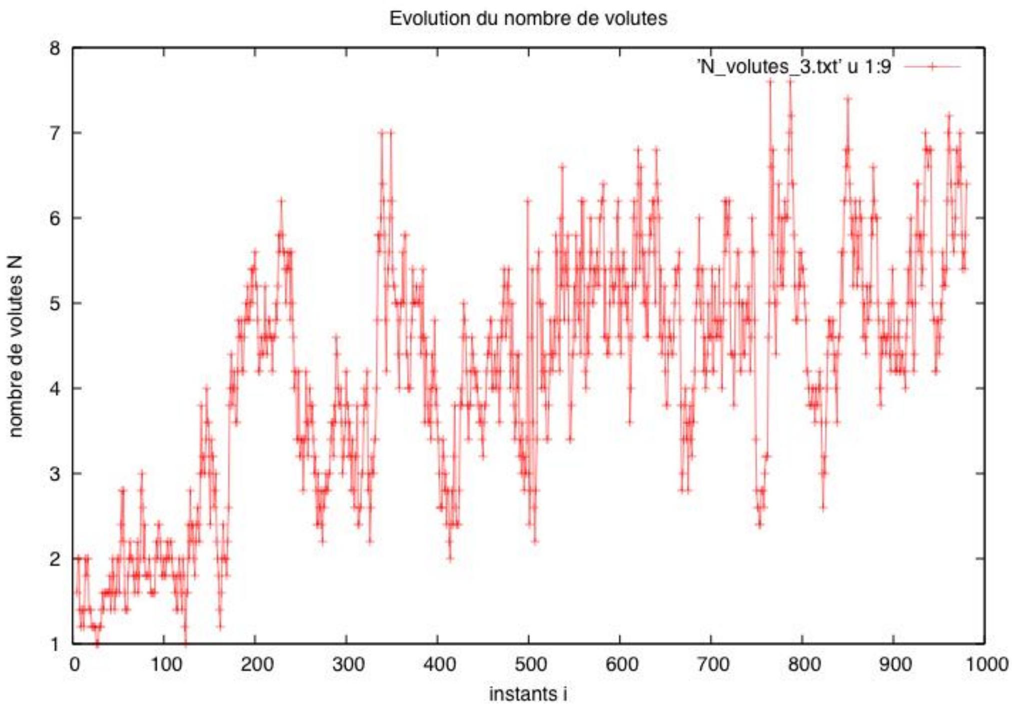


Figure 6: Temporal evolution of the plumes number.